Journal Of Integrated Engineering And Management Sciences
ISSN: **3139-5511,**Volume-1 Issue-2, April-June 2026 | **JIEMS-1203**
DOI: https://doi.org/10.5281/zenodo.22336261.

REMOVAL OF RHODAMINE 6G DYE FROM WATER SOLUTION BY ALT-MALEIC ANHYDRIDE-STYRENE COPOLYMER, CROSS-LINKED WITH GLYCERIN

*** Dr. CH. SRINIVAS,** *Professor in Mechanical & Principal*
VAAGESWARI COLLEGE OF ENGINEERING(AUTONOMOUS), KARIMNAGAR

ABSTRACT- The Rhoda mine 6G dye was extracted from water using a copolymer consisting of styrene, alt-maleic anhydride, and glycerin. The degree of elimination was examined in relation to temperature, sorbent quantity, contact time, initial dye concentration, and solution pH. We used Freundlich, D-R, and Langmuir isotherms to check the consistency of the equilibrium sorption results. According to the Langmuir equation, the maximum amount of sorption that can occur at equilibrium is 14.73 mg g-1. Using the D-R equation and the mean sorption energy of the Rhoda mine 6G dye (5.472 kJ mol-1), we can evaluate its effect on the polymer-sorbent. We studied the surface properties and geometry of dye-loaded sorbents after sorption using scanning electron microscopy (SEM). SEM images demonstrated a relationship between sorbents with uneven surfaces and Rhoda mine 6G dye molecules. The pseudo-second-order model corresponded well with the motion data. The adsorption process is planned, unpredictable, and ultimately resulting in heat, as evidenced by the positive thermodynamic values of G° (7.45-6.04 kJ mol-1), H° (18.378 kJ mol-1), and S° (0.0374 kJ mol-1K-1).

Key words: Adsorption, Cross-linked copolymer, Isotherms, Kinetic, Rhoda mine 6G dye

1. INTRODUCTION

Polluting colors cannot be recycled due to their synthetic character and aromatic chemical compositions. Water pollutants similar to these may be found in factory wastewater. Even in small amounts, color can alter the chemical and physical properties of water, making it appear unpleasant. Scientists have established a link between subcutaneous tissue-borne malignancy and water containing rhodamine color. Color is removed from water-containing solutions using a variety of physical, biological, and chemical processes. This category includes biological oxidation, flocculation, filtration, ion exchange, biological osmosis, chemical precipitation, solvent extraction, and membrane processes. The results show that Rhodamine 6G (Rh 6G) was recovered from water-based solutions utilizing the poly (fumaric acid-co-acrylic acid) adsorbent surface. Adsorption effects on temperature, ionic strength, contact time, pH, and adsorbent quantity were investigated. Hydrogel can be used to successfully remove Rh 6G dye from water-based devices. The Freundlich, Temkin, and Langmuir models were used to examine the equilibrium adsorption data. Microparticles cross-linked with poly (N-vinyl caprolactam-co-maleic acid) were used to remove Rh 6G from water. We were able to investigate the effects of starting pH, adsorbent dosage, temperature, dye concentration, and contact time on dye adsorption using batch adsorption. The equilibrium adsorption

ISSN: **3139-5511,**Volume-1 Issue-2, April-June 2026 | **JIEMS-1203**
DOI: https://doi.org/10.5281/zenodo.22336261.

results better fit the Langmuir isotherm model. The largest quantity of Rh 6G that could be absorbed at pH 10 was 2012 mg/g. A roughly second-order model could fit the experimental results. Chitosan-g-(N-vinyl pyrrolidone) montmorillonite complexes absorb the Rh 6G dye and water. Adjusting the sorbent quantity and touch time enhanced absorption. Despite the temperature increase, no alterations were seen. The Rh 6G adsorption dynamics and equilibrium numbers can be used to match the Freundlich model. In batch sorption investigations, researchers studied the efficacy of powdered palm shell in removing Rh 6G from water solutions. We changed the starting dye concentration, contact time, solution pH, and adsorbent mass during this work. Adsorption data was modeled using pseudo-first- and pseudo-second-order equations to examine sorption. The most effective model for explaining the adsorption dynamics was a pseudo-second-order model. To investigate equilibrium, Freundlich and Langmuir isotherms were used. The parameters of the model were all defined. At 25°C, the exhausting capacity of Rh 6G was 105.0 mg g1. As demonstrated by the negative drop in free energy, adsorption happened independently. Suffocated poly (styrene [ST]-alt-maleic anhydride [MA]) microspheres were produced from poly (St-alt-MA) using a sulfonation process to evaluate their effects on the adsorption of organic dyes. In terms of eliminating cationic dyes, the adsorbent surpassed poly (St-alt-MA). We investigated the adsorption rates and isotherms of rhodamine dyes extracted from aqueous solutions using used coffee grounds. The sorption behavior was investigated while taking fluid volume, anions, temperature, and ionic strength into account. A hyper hydrophilic absorbent based on chemically modified chitosan was also created and tested for absorbing Rh 6G dye from water-based solutions. We also discussed how effectively this absorbent removes pigment. Adjustable variables include the pH of the solution, the time of contact, the starting dye concentration, and the amount of adsorbent. 80.34 percent of the dye was removed using a sorbent dose of 1.0 g L1 and a pH of 10. A mixture of acrylic acid, sodium acrylate, acrylamide, and dim ethyl acrylate was dried and left to sit for a long time to see how ethylene blue and Rh 6G connected. At equilibrium, the sorption capacities and adsorption rate constants were determined. As the mole% of acrylamide grew, the equilibrium color absorption dropped. Both inflated and dry sorbents absorb the same quantity of water. The expanded sorbent absorbed the colors faster than the dry one. When the sorbent was fully stretched, the existence of all negatively charged groups that aid in adsorption was ensured. The Langmuir adsorption isotherm was used to determine how the initial dye concentration affected the adsorption process. Batch adsorption was used to explore the binding mechanism of Rh 6G to betonies. The adherence of Rh 6G was found to be influenced by a number of parameters, including pH, starting concentration, adsorbent dosage, contact time, and temperature. We used the Freundlich, Temkin, and Langmuir models to examine the equilibrium adsorption data and derive the isotherm values. Pseudo-second-order rate variations in Rh 6G have been seen on betonies. Using Fe3O4 nanoparticle compositions, magnetic biochar made

CC BY NC

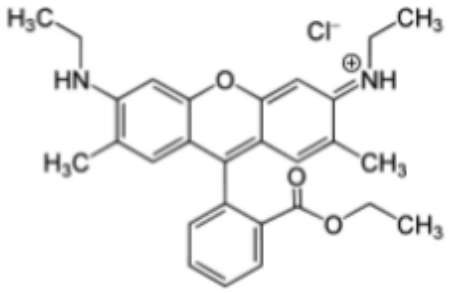
Journal Of Integrated Engineering And Management Sciences
ISSN: **3139-5511,**Volume-1 Issue-2, April-June 2026 | **JIEMS-1203**
DOI: https://doi.org/10.5281/zenodo.22336261.

from rice husk was tested for its efficiency in removing the Rh 6G dye. We investigated the kinetic, thermodynamic, and isothermal aspects of Rh 6G dye adsorption on magnetic biochar. The Fe3O4-composite biochar eliminates Rh 6G 94% more effectively than pure biochar. Kinetic and adsorption isotherm experiments confirmed that the Langmuir, pseudo-first-order, and pseudo-second-order models we used to predict Rhodamine adherence to magnetic Fe3O4-biochar were correct.

2. EXPERIMENTAL

2.1Materials and Methods

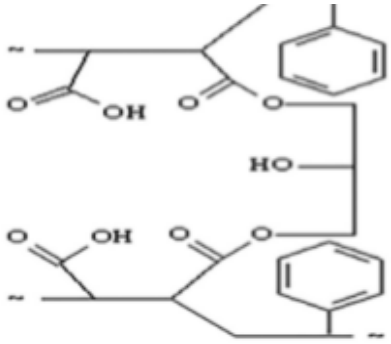
A solution including glycerin, maleic anhydride, and styrene was tested for its ability to remove Rh 6G from water. The researchers investigated how pH, sorbent amount, contact time, temperature, and initial dye concentration affected sorption. To evaluate the equilibrium adsorption data, we used the Freundlich, Dubinin-Radushkevich (D-R), and Lanmuir models. Figures of the thermodynamic and kinetic adsorption parameters were presented, as well as a description of the possible sorption process.



Prior to application, impurities were eliminated from MA by recrystallization from benzene. Distillation was used to heat the styrene (St) to a suitable temperature of 144-145°C. To clean it up, azobisisobutyronitrile has to be recrystallized from ethanol. The adsorb ate was discovered to be Rh 6G chloride, a monovalent cationic dye. C28H31ClN2O3 is the chemical formula for Rh 6G powder. This color is known as C.I. Basic Red 1 because of the chemicals it contains and the type of dye it is.

2.2. Preparation of Adsorbent

The alt-MA-St copolymer, which is coupled with glycerin (MSG) and has functional groups (−COOH, OCO, −OH, and C=O), was created in two steps. To begin, a combination of 50 ml of benzene, 4.9 g of MA, 4.16 g of St (in a 1:1 molar ratio), and 0.1 g of AIBN was heated to 80°C. Frozen in ethanol or heptane, the copolymer (CPL) was then dried in a pressure oven at 40°C to get 6.7 g, or 72.6%. According to the results of the chemical analysis, 51.5% of SPL is MA and 48.5% is St. Second, for three hours, bring 4.08 grams of SPL and 5.0 grams of GL to a temperature of 120°C. To remove the non-reacting GL and SPL, the functional cross-linked polymer was washed multiple times with alcohol and double-distilled water. The polymer sorbent has been vacuum dried to a temperature of 30°C. Made and connected adsorbent.



2.3. Adsorption Experiments

A stock solution dye with concentration 500 mg L−1 was prepared in double-distilled water and the experimental solutions with the desired concentration were obtained by dilutions stock solution.

Journal Of Integrated Engineering And Management Sciences
ISSN: **3139-5511,**Volume-1 Issue-2, April-June 2026 | **JIEMS-1203**
DOI: https://doi.org/10.5281/zenodo.22336261.

Diluting 500 mg L−1 of dye stock solution in double-distilled water yielded the correct concentration for the tests. The adhesion of the Rh 6G dye to a synthetic sorbent was investigated using the same methodology as in our earlier studies. The sorption degree (%) and capacity (mg g−1) of the sorbent were determined using Equations (1) and (2).

$$Sorption\ \deg ree = \frac{(C_0 - C_e)}{C_0} \times 100\% \quad (1)$$

$$Sorption\ capacity = \frac{(C_0 - C_e) \times V_{sol}}{m_{sorb}} \quad (2)$$

The variables Vsol, msorb, and Ce display the following values: initial and final concentrations of Rh 6G (in milligrams per milliliter), sorbent weight, and amount of dye solution absorbed.

3. RESULTS AND DISCUSSION

3.1. Effect of Ph

The effect of pH on the Rh 6G dye sorption degree was investigated at an initial dye concentration 75 mg L−1, sorbent weight of 3.0 g L−1, sorption time of 30 min, and temperature of 20°C. Under these conditions, the pH of the solution changed in the range of 3–9. The results show that in a strongly acidic medium, the sorption degree is low (5.6%); the maximum sorption degree (21.0%) is observed at pH = 6. However, increase in solution pH results in reduction of sorption degree to 16.2%. The low adsorption of Rh 6G at acidic pH was suggested to be due to the presence of excess H+ ions in solution. For cationic dyes, the lower adsorption of the dye at strong acidic medium is likely due to the presence of an excess H+ ions, which compete with the cationic groups of the dye at the active sites of the adsorbent . As surface charge density decreases with an increase in the pH solution, the electrostatic repulsion between the positively charged dye and the surface of the adsorbent is lowered, which may result in an increase in the extent of adsorption . With an increase in the pH of solution, the electrostatic repulsion between the positively charged cationic dyes and the surface of adsorbent is lowered and consequently the removal efficiency is increased . Thus, the larger values found at pH above 3 are explained by electrostatic attraction forces between the immobilized negatively charged sorbent and the positively charged dye ions. In view of the relatively high sorption degree of the Rh 6G by the synthesized adsorbent at pH 6, subsequent experiments were carried out at pH 6.

3.2. Effect of Sorbent Dosage

The quantity of dye extracted from water-based solutions varies with the concentration of sorbent employed in specific experiments, as shown in Table 1. From 1.0 to 4.0 g L1 of sorbent was utilized for the sorption process. According to the results, the removal level drops significantly as the sorbent concentration gets close to 3.0 g L1. There is minimal correlation between increasing the sorbent concentration and the sorption level. A volume of 3.0 g L1 of sorbent is optimal under the specified experimental conditions. Subsequent experiments made use of 3.0 g L1 of sorbent.

3.3. Effect of Contact

Quicken the speed The contact time influences the binding rate of a sorbate at its initial concentration. We investigated the capacity of the synthesized sorbent to remove Rh 6G dye for 20 to 150 minutes under controlled conditions (Table 2). The impact of contact time on this capacity was studied. Finally, the results showed that the elimination of Rh 6G had reached

Journal Of Integrated Engineering And Management Sciences
ISSN: **3139-5511,**Volume-1 Issue-2, April-June 2026 | **JIEMS-1203**
DOI: https://doi.org/10.5281/zenodo.22336261.

equilibrium. 3.7% of Rh 6G remained attached over the first 20 minutes after sorption. After 120 to 150 minutes, the color of MSG approaches equilibrium. The sorbent reduced Rh 6G to the tune of 28.8 to 29.5%. The Rh 6G dye absorbs the water about 120 to 150 minutes

Table 1: Effect of sorbent dosage (rhodamine 6G concentration 200 mg L–1, V=0.04 L, 20°C, 30 min)

Sorbent dosage, g L–1	1.0	1.5	2.0	2.5	3.0	3.5	4.0
Removal degree, %	1.5	5.5	10.2	12.3	12.6	13.0	13.1

Table 2: Effect of time on sorption degree (initial rhodamine 6G concentration 200 mg L–1, V=0.04 L, sorbent dosage 3.0 g L–1, 20°C)

Time, min	20	30	40	60	80	100	120	150
Removal degree, %	3.7	12.6	14.6	19.1	22.3	25.5	28.8	29.5

3.4. Effect of Dye Concentration on Sorption Degree and Sorption Capacity

We performed constant-state tests on dye solutions with starting concentrations ranging from 75 mg L1 to investigate the effect of increasing the Rh 6G concentration on the dye's stickiness and capacity to retain. Table 3 summarizes the findings. The removal rate drops from 19.0 to 11.8% when the sorbent's dye-absorbing capacity increases from 4.74 to 9.83 g g1. At 200 mg L-1, there is an effective equilibrium. When the sorbent's active sites are filled, the sorption degree decreases with increasing dye concentration. This means that the sorbent has the ability to stabilize 9.83 grams of material

3.5. Effect of Temperature

This table shows the adsorption of Rh 6G dye with MSG at various temperatures (20 to 60°C), dye concentrations (200 mg L1), pH levels (6.0), and contact times (half an hour). Table 4 demonstrates that at 60°C, sorption increases to 25.5%. The sorption strength increases as the temperature rises due to the increased mobility of the dye molecules and their interactions with the sorbent's active sites. The fact that the sorption degree fluctuates with temperature demonstrates the endothermic nature of the MSG-Rh 6G dye adsorption

3.6. Langmuir, Freundlich, and DR Isotherms

When doing monolayer adsorption, the Langmuir isotherm value is assumed to be constant across all adsorption sites

Table 3: Effect of dye concentration on sorption degree and sorption capacity (sorbent dosage 3.0 g L–1, 30 min, 20°C, V=0.04 L)

Initial concentration, mg L^{-1}	75	100	125	150	175	200	225	250
Sorption degree, %	19.0	18.0	15.8	14.5	13.2	12.6	12.1	11.8
Sorption capacity, g g L^{-1}	4.74	6.0	6.58	7.26	7.7	8.4	9.07	9.83

Table 4: Effect of temperature on sorption degree (initial Rh 6G concentration 200 mg L–1, V=0.04 L, 30 min)

Temperature, °C	20	30	40	50	60
Removal degree, %	12.6	15.0	19.1	23.0	25.5

incorporating the fact that absorption rates vary depending on location. Equation (3) depicts the Langmuir isotherm.

$$C_e/q_e = 1/(q_{max} K_L)+C_e/q_{max} \quad (3)$$

Ce displays the balanced amount of Rh 6G (mg L-1). The value of qe represents the quantity of adsorption. In this situation, qmax is the maximum quantity that the MSG monolayer can absorb. KL finally proves the Langmuir equilibrium constant. The Freundlich isotherm equation indicates that adsorption relies on site energy because various surfaces have varying energies at their sites. Equation (4) discusses the Freundlich isotherm

$$\log q_e = \log K_F+(1/n) \log C_e \quad (4)$$

There is also the Freundlich constant KF, in addition to the variability factor 1/n. The Freundlich and Langmuir isotherm

Journal Of Integrated Engineering And Management Sciences
ISSN: **3139-5511,**Volume-1 Issue-2, April-June 2026 | **JIEMS-1203**
DOI: https://doi.org/10.5281/zenodo.22336261.

models were used to examine the experimental results on equilibrium. The equilibrium concentration at 60 minutes with a pH of 6, a sorbent dose of 3.0 g L-1, a volume of 0.04L, and a temperature of 20°C is shown in Figures 1 and 2. As a starting point, the linear specific sorption of Rh 6G in solution is used. We were able to determine the values of the Freundlich and Langmuir isotherms using the plot slope intercepts, which are shown in Table 5. According to the Langmuir equation, the highest equilibrium sorption capacity is 14.73 mg g-1. This value is closer to the mark, with an experimental result of 9.83 mg g-1.

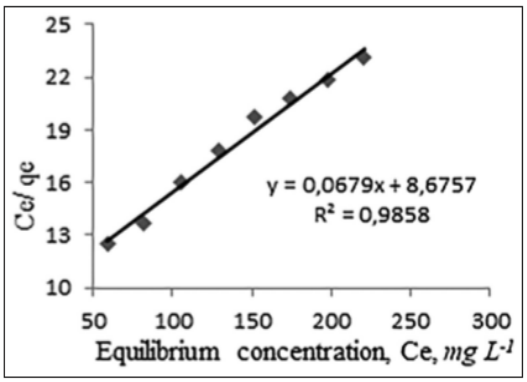


Figure 1: Langmuir plot for the rhodamine 6G sorption

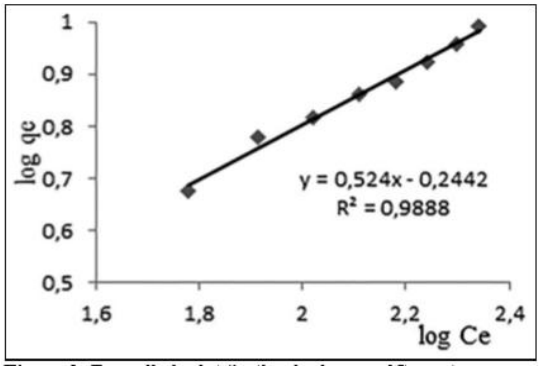


Figure 2: Freundlich plot for the rhodamine 6G sorption:

Table 5: Langmuir, Freundlich, and D-R equations parameters (initial Rh 6G concentration 75–250 mg L–1, V=0.04 L, sorbent dosage 3.0 g L–1, 30 min, 20°C)

Langmuir equation				Freundlich equation				D-R equation			
q_{max}, mg g^{-1}	K_L, L mg^{-1}	R_L	R^2	1/n	n	K_F	R^2	K_D, $kJmol^{-1}$	B_{DR}, mmol g^{-1}	E, $kJmol^{-1}$	R^2
14.73	0.00783	0.63–0.338	0.9858	0.524	1.908	3.342	0.9888	0.0334	0.0254 (12.17 mg/g)	5.472	0.9695

The Langmuir isotherm equation estimates the feasibility of adsorption by using the equilibrium constant (KL) and the separation coefficient (RL). Equation (5) is used to calculate the RL, or dimensionless separation coefficient.

$$R_L = 1/(1+K_L\, Co) \quad (5)$$

Co. 1 > RL > 0 is considered good, RL > 1 is considered poor, RL = 1 is linear, and the initial RL value of 0 cannot be adjusted for the adsorbate concentration [18]. Our calculated RL values of 0.630-0.338 for Rh 6G starting concentrations of 75-250 mg L-1 suggest that the dye adsorbs efficiently with MSG. The D-R isotherm, as indicated in Equation (6), is commonly used to distinguish between physical and chemical adsorption

$$ln\, q_e = -K_D \varepsilon^2 + lnB_{DR} \quad (6)$$

The BDR theoretical isotherm saturation capacity (mol g-1), the equilibrium adsorption capacity (qe), the Polanyi potential (), and the D-R equation constant (KD) are all displayed in Equation (7

$$\varepsilon = RT\, ln\,(1+1/Ce) \quad (7)$$

The BDR theoretical isotherm saturation capacity (mol g-1), the equilibrium adsorption capacity (qe), the Polanyi potential (), and the D-R equation constant (KD) are all displayed in Equation (7).

$$E_D = 1/(2\, K_D)^{½} \quad (8)$$

The ED number might tell you about the sort of adsorption: The ED must be greater than 16.0 KJ mol-1 to be categorized as chemical adsorption. When ED is less than 8.0 KJ mol-1, physical adsorption occurs [19]. Figure 3 depicts a function known as lnqe = f (2) for the D-R equation. It is successful when the following parameters are met: pH 6, 30 minutes of contact time,

Journal Of Integrated Engineering And Management Sciences
ISSN: **3139-5511,**Volume-1 Issue-2, April-June 2026 | **JIEMS-1203**
DOI: https://doi.org/10.5281/zenodo.22336261.

Co=75-250 mg L-1, V = 0.04 L, 3.0 g L-1, and a sorbent dosage of 20°C. Table 5 shows the calculated values. The D-R equation can be used to calculate the sorbent's (BDR) capacity to retain 0.0254 mmol g-1 (12.17 mg g-1). A synthetic polymer sorbent physically absorbs Rh 6G with an ED value of 5.472 kJ mol-1 8.0 kJ mol-1..

3.7. Sorption Kinetics and Thermodynamic

Under optimum conditions, kinetic tests lasting 20 to 150 minutes were carried out. When it came to kinetic data, the linear Lagergren pseudo-first- and pseudo-second-order models performed brilliantly. Model of hyperbolic first-order kinetics In the following equations,

$$log\,(q_e - q_\tau) = log q_e - 0.434K_1 \quad (9$$

The values of q and qe, which represent the sorption capacity with time and at equilibrium (mol g-1), are shown. The rate constant (min-1) of the pseudo-first-order kinetic model is represented as K1. One way to understand the pseudo-second-order kinetic model is by looking at Equation 10

$$\tau/q_\tau = 1/(K_2 q_e^{\,2}) + \tau/q_e \quad (10$$

K2, the pseudo-second-order equilibrium rate constant in moles per minute, q, the sorption capacity at time, and qe, the equilibrium sorption capacity in moles per gram, are our variables. The pseudo-first and pseudo-second model equations are shown in Figures 4 and 5, respectively. The sorbent dosage is 3.0 g L-1 at 20°C, 0.04 liter volume, and pH 6. The kinetic parameter data are provided in Table 6. In comparison to the pseudo-first-order model, which has a lower correlation coefficient, the pseudo-second-order model depicts the Rh 6G dye binding process with MSG more clearly. Previous research findings were compared to the Rh 6G dye adsorption data from the produced sorbent MSG (Table 7). Our study looks at the temperature-dependent variations in Rh 6G adsorption on MSG using thermodynamic metrics like standard enthalpy change (°), standard entropy change (°), and standard Gibbs free energy (h°). Equations 11-13 can be used to calculate these values.

Table 6: Regression parameters for the kinetics models (initial Rh 6G concentration 200 mg L–1, V=0.04 L, sorbent dosage 3.0 g L–1, 20°C)

Kinetic model parameters					
Pseudo-first order			Pseudo-second order		
q_e, mg g^{-1}	K_1, min^{-1}	R^2	q_e, mg g^{-1}	K_2, min^{-1}	R^2
32.48	0.003	0.8892	31.545	0.00071	0.9894

Table 7: Comparison of Rh 6G dye uptake data with other adsorbents

Sorbent	q_{max}, (mg g^{-1})	pH	Adsorbent, (g L^{-1})	Model	Source
Activated carbon	44.7	7	0.02	Langmuir	[24]
Palm shell powder	105.0	5.75	0.4	Langmuir	[23]
Biological sludge	16.3	7	10.0	Langmuir	[22]
Coffee ground	17.37	—	1.0	Langmuir	[8]
Trichoderma harzianum mycelial biomass	3.40	8	2.0	Langmuir	[24]
Chitosan-g-(N-vinylpyrrolidone)/ montmorillonite hydrogel	36.6	10	0.05	Freundlich	[5]
Bentonite clay	111.11	6	4.0 g	Langmuir	[11]
Cross-linked maleic anhydride-styrene copolymer	14.73	6	3.0	Langmuir	In this study

Journal Of Integrated Engineering And Management Sciences
ISSN: **3139-5511,**Volume-1 Issue-2, April-June 2026 | **JIEMS-1203**
DOI: https://doi.org/10.5281/zenodo.22336261.

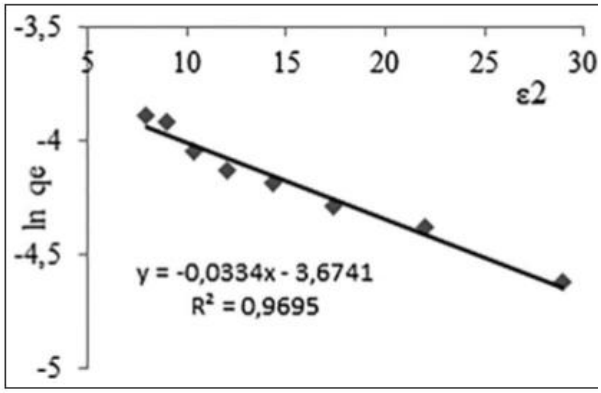


Figure 3: Dubinin-Radushkevich plot for the rhodamine 6G sorption.

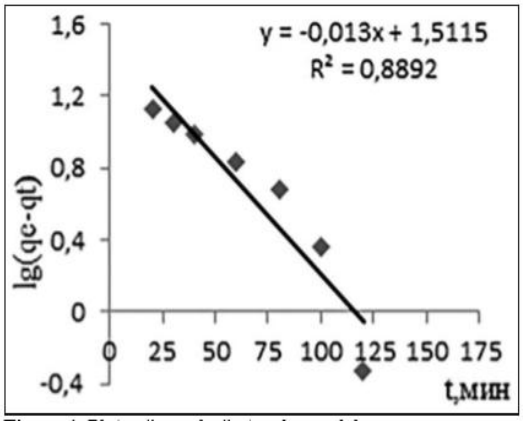


Figure 4: Plots of pseudo-first-order models.

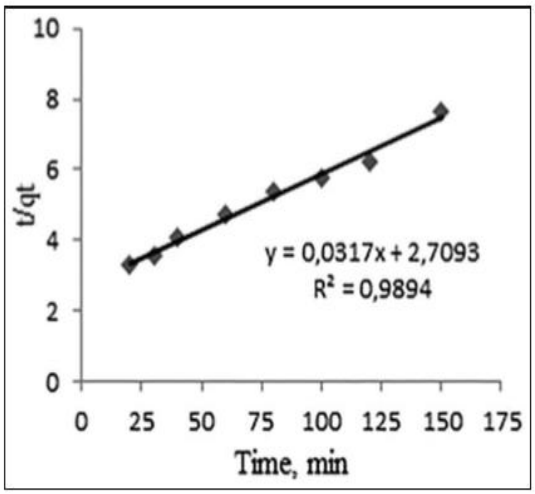


Figure 5: Plots of pseudo-second order.

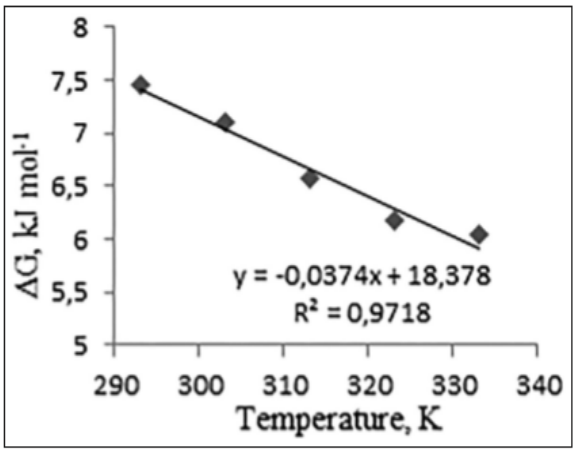


Figure 6: Plot of ΔG° versus T.

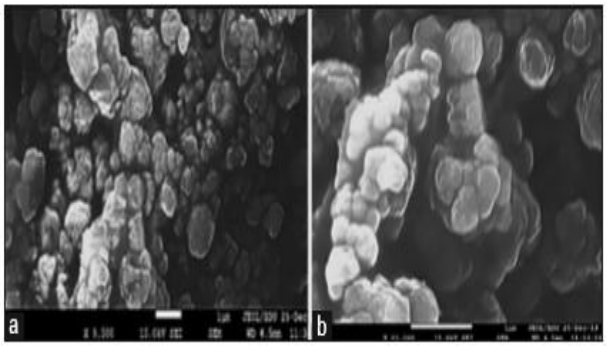


Figure 7: SEM image of the rhodamine (Rh) 6G-loaded sorbent: (a) ×9500 and (b) ×25,000 (light sites the adsorbed Rh 6G dye).

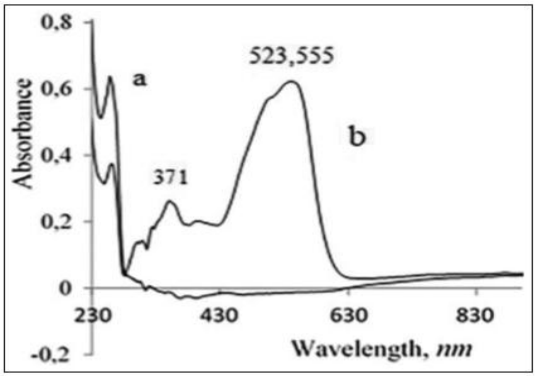


Figure 8: UV–visible spectra of the MSG: (a) Before and (b) after sorption

$$\Delta° = -2,3\ RT\ log K_d \quad (11)$$

$$K_d = q_e/C_e \quad (12)$$

$$\Delta G° = \Delta H° - T\Delta S° \quad (13)$$

T is the exact temperature, while R denotes the gas constant (8.314 J mol-1 K-1). Kd is the equilibrium constant at temperature T. Figure 6 depicts the values

Journal Of Integrated Engineering And Management Sciences
ISSN: **3139-5511,**Volume-1 Issue-2, April-June 2026 | **JIEMS-1203**
DOI: https://doi.org/10.5281/zenodo.22336261.

of H° and S° derived from the slope and intercept of G° against T plots. These can be found in Table 8. The positive H° (18.209 kJ mol-1) indicates that the adsorption is endothermic. When S° is positive, which is 0.3691 kJ mol-1 K-1, the adsorption process becomes less steady.

Table 8: Sorption thermodynamic parameters (pH 6, 30 min, Co= 0.365 mmol L–1, V=0.04 L, sorbent dosage 3.0 g L–1)

Temperature, TK	Thermodynamic parameters		
	ΔG°, k J mol^{-1}	ΔH°, k J mol^{-1}	ΔS°, k J $mol^{-1}K^{-1}$
293	7.45		
303	7.11		
313	6.57	18.378	0.0374
323	6.19		
333	6.04		

3.8. Mechanism of the Adsorption

The mechanism of Rh 6G dye absorption by MSG was determined using a SEM picture and the adsorbent's post-sorption UV band. Figure 7, a SEM image, shows that the Rh 6G dye molecules appear to gather on the uneven surface of the sorbent. Figure 8 depicts MSG's pre- and post-absorption UV spectrum. According to the sorbent's UV spectra, the dye sorbent complex attaches at 371 nm, but the Rh 6G dye clings to a surface between 523 and 555 nm (Figure 8b). Many studies have been written about the possibilities of Rh 6G interacting with acidic polymers like maleic acid copolymers. The 350-370 nm highs are caused by phenolic acid copolymers with Rh 6G complexes. The dye's kinetic and thermodynamic characteristics, as well as SEM and UV spectroscopy of the sorbent after sorption, show that electrostatic adsorption of the Rh 6G dye occurs at MSG active sites. The average sorption energy of Rh 6G (ED = 5.472 kJ mol-1 8.0 kJ mol-1) indicates that it is physically connected to a polymer sorbent

4. CONCLUSIONS

The best parameters for Rh 6G dye sorption from water to MSG were identified by examining the effects of pH, contact time, sorbent dosage, temperature, and initial dye concentration. The equilibrium sorption results were used to fit the Freundlich, D-R, and Langmuir models. The highest amount of sorption that can occur at equilibrium, according to the Langmuir equation, is 14.73 mg g-1. The separation factor RL values ranged from less than 1 to greater than 0 at varying initial concentrations of Rh 6G, indicating good adsorption. The pseudo-second-order model proved the most useful for sorption dynamics. If H° is more than 18.378 kJ mol-1, the sorption process is endothermic. Adsorption becomes less reliable when the S° value is positive (0.0374 kJ mol-1 K-1). Electrostatic contact forces are the method by which the Rh 6G dye interacts with the active sites of MSG, according to surface plasmon resonance (SEM) microscopy, ultraviolet (UV) spectra of the sorbent before and after sorption, and thermodynamic and kinetic parameters. The average sorption energy of Rh 6G (ED = 5.472 kJ mol-1 8.0 kJ mol-1) indicates that it is physically connected to a polymer sorbent. Finally, glycerin and the cross-linked alt-MA-St copolymer perform effectively as an absorbent to extract the Rh 6G color from aqueous solutions.

5. REFERENCES

1. M. Jain, S. Mathur, S. Sikarwar, A. Mittal, (2007) Removal of the

ISSN: **3139-5511,**Volume-1 Issue-2, April-June 2026 | **JIEMS-1203**
DOI: https://doi.org/10.5281/zenodo.22336261.

hazardous dye rhodamine B through photocatalytic and adsorption treatments, Journal of Environmental Management, 85: 956-964.

2. V. J. P. Vilar, C. M. S. Botelho, R. A. R. Boaventura, (2007) Methylene blue adsorption by algal biomass, based materials: Biosorbents characterization and process behavior, Journal of Hazardous Materials, 147: 120-132.
3. L. Wissam, L. Benyan, (2019) The adsorptive removal of rhodamine 6G dye from aqueous solution by using poly (fumaric acid-co-ACRYLIC ACID) hydrogels, Journal of Global Pharma Technology, 11: 263-272.
4. Popescu, D. M. Suflet, (2016) Poly (N-vinyl caprolactam-comaleic acid) micro particles for cationic dye removal, Polymer Bulletin, 73: 1283-1301
5. Vanamudan, K. Bandwala, P. Pamidimukkala, (2014) Adsorption property of rhodamine 6G onto chitosan-g-(N-vinyl pyrrolidone)/montmorillonite composite, International Journal of Biological Macromolecules, 69: 506-513.
6. G. Sreelatha, P. Padmaja, (2008) Study of removal of cationic dyes using palm shell powder as adsorbent, Journal of Environmental Protection, 2: 63-71.
7. Y. Li, W. Nie, P. P. Chen, Y. F. Zhou, (2016) Preparation and characterization of suffocated poly (styrene-alt-maleic anhydride) and its selective removal of cationic dyes, Colloids and Surfaces A: Physicochemical and Engineering Aspects, 499: 46-53.
8. K. Shen, M. A. Gondal, (2017) Removal of hazardous rhodamine dye from water by adsorption onto exhausted coffee ground, Journal of Saudi Chemical Society, 21: 120-127.
9. N. Bhullar, K. Kumari, D. Sud, (2017) Studies on chitosan-based super hydrophilic adsorbent for phasing out rhodamine 6G dye and Cd2+ ions from aqueous solutions, Desalination and Water Treatment, 95: 355-364.

CC BY NC